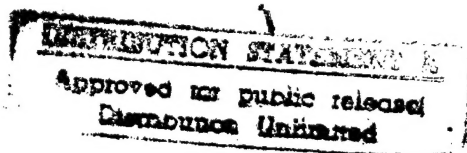**DATE:** 3/20/97

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National Center for Atmospheric Research Evaluates TECOM Meteorological Support for Testing

Meteorological support within the U.S. Army Test and Evaluation Command (TECOM) must be enhanced in its ability to test and evaluate new and more complex materiel, such as smart munitions, in order to reduce the resources necessary for test and evaluation.

In light of this challenge, the TECOM Atmospheric Sciences Division (ASD) decided last summer that it should not rely solely on in-house perceptions of meteorological support during this critical period of transition, but should seek an independent review and evaluation of TECOM meteorological support. The National Center for Atmospheric Research (NCAR) was selected to perform this evaluation because it is a center of international scientific excellence.

The Meteorology and Modeling Division at West Desert Test Center (WDTC), U.S. Army Dugway Proving Ground, was asked by TECOM to be the technical liaison for the NCAR evaluation.

TECOM asked NCAR to review and evaluate current and future TECOM meteorological support requirements and capabilities, and recommend how recent technological developments could enhance meteorological support in areas such as test-specific weather forecasts, evaluation of meteorological influences on test results, and the inclusion of realistic atmospheric effects in virtual proving ground (VPG) modeling.

NCAR gained knowledge of TECOM meteorological support tasks and functions through a systematic information- gathering process developed in collaboration with WDTC. Questionnaires resulting from this collaboration were sent to TECOM test center technical directors and meteorological unit chiefs.

An NCAR field team of scientists, engineers, and program managers also visited TECOM test centers at Redstone, White Sands, Yuma, Dugway, and Aberdeen. The site visits helped the team better identify user needs for meteorological information, and review existing processes and facilities for providing it.

The NCAR team also met with test center managers, test directors, project engineers, administrative staff, and range support personnel to better understand meteorological support needs and the role of the meteorology units within these test centers. Because proposed technological solutions would have to be integrated into each range's test support infrastructure, NCAR also reviewed the existing and planned data processing and sensor networking capabilities at various ranges.

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Why Weather is Important

Weather and terrain have a greater impact on battles than any other physical factor, including weapons. Although Army weather testing requirements issues were raised by Kullberg in 1986, the Army did not identify any meaningful, overall requirements for determining the effects of meteorological conditions on materiel during test and evaluation other than Military Standard 810E (Test Methods and Engineering Guidelines).

Despite this absence of overall Army weather test requirements, meteorological sensors at TECOM ranges are quite good and provide a data-rich environment. Also, TECOM estimates that about $1 million will be spent in each of the next three fiscal years for global positioning system (GPS) upper-atmospheric sounding systems, wind profilers, and transmissometers, as well as for planned upgrades to the surface atmospheric measurement system (SAMS) automated weather stations.

Operational field tests typically relate the performance of test articles or weapon systems to a limited range of surrogate battlefield conditions, including weather. This is even more true of meteorological requirements for developmental testing of materiel which appears to be negotiated on a case-by-case basis by program managers and test directors. These requirements seem to be primarily directed toward identifying suitable weather conditions for testing, given known test article sensitivities, safety concerns, and environmental constraints.

For example, NCAR was told by test directors at several ranges that meteorology requirements were important during development only if the test article failed. Difficulties supporting overall performance requirements in testing new weapon systems in varied meteorological conditions led the Department of Defense to establish a test and evaluation operability-enhancement program for advanced weapons.

Called the Smart Weapons Operability Enhancement (SWOE) Joint Test and Evaluation Program, this program could be a harbinger for how the meteorological effects on test articles will be identified in future developmental test and evaluation. SWOE uses models and algorithms of atmospheric physics to produce engineering performance specifications for high-fidelity infrared scenes, under measured meteorological conditions.

NCAR identified four serious meteorological problem areas in its evaluation.

Data base networking and retrieval problems at TECOM ranges limit the usefulness of data acquired by various meteorological measurement systems.

Once archived, TECOM meteorological data are not easily retrievable for analyses because the different meteorological systems have separate, stand-alone data archives. In addition, the different systems have different data formats for timing, quantifying, and recording meteorological measurements. Even the recording and storage media for different kinds of meteorological observations are not the same. Also, data at some ranges are missing because some sensors are operated only during duty hours, because TECOM meteorological units cannot access other meteorological data networks, or because of undetected sensor failures.

The absence of a data assimilation scheme to combine diverse meteorological observations in common temporal and spatial scales is the most severe problem facing TECOM meteorological units.

This data assimilation problem compounds the data base and data networking limitations cited above. Meteorological units need a common data assimilation scheme for all sensors, with uniform temporal and spatial scales. A data assimilation scheme also could quantify meteorological parameters at locations where there are no measured data. Currently, meteorological units subjectively estimate data values for locations where there are no observations, or assume that they are the same as measured data taken at a different time and place.

The need for improved range-scale, atmospheric models was widely recognized by meteorological unit chiefs.

Most of the models currently used by the meteorology units cannot consider time-varying weather conditions or predict small-scale atmospheric features related to local terrain. Most current TECOM models accept only steady-state meteorological input parameters for a specific time, which means that they cannot predict outcomes based upon changes in atmospheric conditions. In addition, current TECOM models cannot adequately predict range-specific terrain effects on the atmosphere because the hydrostatic assumption of these models does not allow adequate resolution of local conditions.

Meteorology units need appropriate decision-support displays.

Various users of meteorological data on TECOM ranges do not have the information they need to do their jobs efficiently. Different users of meteorological information such as forecasters, meteorological technicians, test directors, and post-test analysts have differing data display needs. The needs of other potential users of TECOM meteorological information have not been adequately identified. In addition to poorly defined information needs, not all of the currently collected

meteorological data can be displayed. Most displays are not
user-friendly. Also, meteorology units currently have multiple
displays for different weather measurement systems which are
difficult to integrate to form a composite picture of range
weather.

Lost Opportunities

Taken together, the high cost of retrieving meteorological data,
absence of relevant data, and failure to exploit other sources of
atmospheric information hinder meteorological analysis. As a
result, some of the highest value-added activities meteorologists
could perform for TECOM are not being done.

The lack of a data assimilation scheme for TECOM test ranges has
far-reaching effects. For example, values for gaps in measured
data that could affect test article performance are assumed
because a data assimilation scheme is not available to resolve
differing temporal and spatial scales of measured meteorological
data. The process for making assumptions about missing
meteorological data is generally subjective and linear, and may
be difficult to justify in light of our knowledge of atmospheric
physics. As a result of these shortcomings, the measured
meteorological data routinely provided for inclusion in TECOM
test reports may not reflect the meteorological conditions that
the test article actually encountered.

The limitations of current TECOM meteorological models can have
significant impact on tests.

For example, the required resolution necessary to accurately
predict high-level winds at WDTC for tests involving chemical or
biological simulent dissemination (i.e., chemical or biological
agent detection tests) cannot be obtained with hydrostatic models
currently used by TECOM. As a result, large test teams spend
unproductive hours waiting in the field for favorable weather
conditions to occur. Expensive safety and environmental
"envelopes" currently required for much of TECOM testing could
also be reduced by better, nonhydrostatic atmospheric circulation
models. In addition, placement of meteorological sensors could
be optimized by using range-scale model simulations of the
effects of local topography on the atmosphere. Test article
performance cannot be accurately predicted by VPG applications
models without more realistic atmospheric models.

Many meteorological data users presently do not have access to
TECOM meteorological sensor systems data displays. Because
meteorological data currently cannot be combined on a single
display or combined with range topography, users have a difficult
time mentally compiling this information in a composite picture.
A number of specific, recurring automated user products that
should be developed by the meteorology unit and shipped directly
to end-users are not currently feasible.

The Solutions

NCAR's proposed solutions to the meteorological support problems discussed above build upon a TECOM infrastructure program already underway. In addition to the significant weather-sensor initiative mentioned earlier, a TECOM communications initiative is also underway. The data base networking and retrieval, data assimilation, range-scale modeling, and decision-support display solutions discussed below depend on completion of this communications initiative.

NCAR proposes that TECOM build a discrete, meteorological subnetwork at each test center. To improve data base management at each range, data collection should be continuous and network-connectivity improved. Most important, a central meteorological data repository should be created with the necessary software to make data retrieval automatic and fast. In addition to enhanced communications between data collection sites and the data repository, the meteorological subnetwork would have automated algorithms to improve remote maintenance monitoring efficiency and data quality control practices.

TECOM test centers need a meteorological data assimilation scheme to take advantage of the many sensors and their different attributes, to optimally define the state of the atmosphere over the range. Consequently, NCAR proposes a mathematically based data assimilation method in which the volume of airspace surrounding a test (or test range) is divided into a large number of grid cells (Stauffer and Seaman, 1994). The number of cells in the volume of airspace is determined by the desired spatial resolution of the meteorological parameters. Within each of these cells, a value for every meteorological parameter at each time interval is automatically determined from available observations and the laws of atmospheric physics.

Range-scale modeling applications are critical for growing environmental and health and safety concerns associated with live testing, as well as for the VPG modeling. In addition, test and evaluation of meteorologically sensitive smart weapons with fewer available resources will require TECOM to increasingly rely on range-scale modeling techniques. NCAR proposes range-scale models to forecast winds, temperature, or other critical meteorological parameters.

The ability to capture the interaction of local terrain and the atmosphere is another significant contribution of range-scale models. For example, sound propagation contours can be redefined from successive forecast changes of three dimensional wind and temperature fields over a shoreline. Areas of turbulence due to local surface features can also be predicted with range-scale models, including the highly erratic flow patterns which would affect plume diffusion in the lee of mountains. Although these localized turbulent areas might not be reflected in available sensor measurements, they could still be very significant

to range testing. For example, wind flowing over topographic features can disturb the air as far as 80 kilometers downwind, up to a height of over 27 kilometers.

Meteorological units need smart decision-support displays to make effective use of the data base subnetwork, data assimilation scheme, and range-scale modeling capabilities discussed above. Different meteorological information users need different information to accomplish their work. NCAR proposes a display capability that would allow anything within the meteorological data repository to be retrieved, processed, and analyzed, and displayed to meet the needs of different kinds of end-users.

Enhancing meteorological unit capabilities will require a different kind of thinking about the test and evaluation functions in TECOM than has occurred in the past.

 1. Traditional meteorological information required for range testing appears to have been more related to identifying windows in which test programs could be successfully concluded than to identifying the meteorology-related performance factors of the test items.

This new way of thinking is the context for the solutions NCAR has proposed to enhance meteorology unit capabilities at TECOM ranges.

 2. At each range a meteorological subnetwork with a data repository will alleviate nonretrievable and missing data problems.

 3. A data-assimilation scheme will resolve data gaps and replace unsupported estimates of meteorological conditions around the test article.

 4. Range-scale modeling will allow more cost-effective test planning and test conduct and more realistic VPG simulations by providing high-resolution forecasts of atmospheric parameters.

 5. Better use of these data and analysis capabilities in decision-oriented displays will help users make better decisions with available meteorological information.

    These are the measures that NCAR believes are necessary if weather-related test article performance problems are to be identified during the developmental phase of the acquisition cycle - a major premise of virtual testing.

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